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Full Length Research Paper

Growth response of eight tropical turfgrass species to salinity

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Irrigation seawater of different salinity levels (0, 24, 48 and 72 dSm^{-1}) were applied to experimental plants grown in a plastic pots filled with a mixture of sand and peat (9:1). The results were analyzed using SAS and treatment means were compared using LSD Test. The results indicated that *Paspalum vaginatum* (seashore paspalum) (SP), *Zoysia matrella* (manilagrass) (MG), *Pasplaum vaginatum* local (SPL), *Cynodon dactylon* (common bermuda) (CB), *Cynodon dactylon* (bermuda greenless park) (GLP), *Eremochloa ophiuroides* (centipede) (CP), *Axonopus compressus* (cow grass) (CG) and *Axonopus affinis* (narrowleaf carpet grass) (NCG) experienced a 50% shoot growth reduction at the EC of 39.8, 36.5, 26.1, 25.9, 21.7, 22.4, 17.0 and 18.3 dSm^{-1}, respectively, and a 50% root growth reduction at the EC of 49.4, 42.1, 29.9, 29.7, 26.0 24.8, 18.8 and 20.0 dSm^{-1}, respectively. The ranking for salinity tolerance of selected grasses was SP>MG>SPL>CB>GLP>CP>NCG>CG. The results indicate the importance of the selection of turfgrass varieties according to the soil salinity and seawater salinity levels to be used for irrigation.

Key words: Salinity tolerance, water salinity, turfgrass, seawater

INTRODUCTION

Soil salinity is considered as one of the major factors that reduce plant growth in many regions of the world. Consequently, secondary water sources are increasingly being used to irrigate large turf facilities (Arizona Department of Water Resources, 1995; California State Water Resources control board, 1993). Seawater intrusion in the coastal states (McCarty and Dudeck, 1993; Murdoch, 1987) has added to the salinity problems in turfgrass culture. Sodium chloride (NaCl) is the predominant component contributing to salinity in soils (Jungklang et al., 2003). Therefore, the need for salt tolerant turfgrasses has increased (Harivandi et al., 1992). Salt tolerant turfgrasses are becoming essential in many areas of the world including Malaysia because of salt accumulation on soil, restrictions on groundwater use and saltwater intrusion into groundwater (Hixson et al., 2004). Physiological responses to salinity include growth suppression and lowered osmotic potential (Marcum, 2006). Salt tolerant plants have the ability to minimize these detrimental effects by producing a series of morphological, physiological and biochemical processes (Jacoby, 1999).

A new generation of salt-tolerant turf varieties might allow landscape development in saline environments and might be ideal in such environments where salt water spray is a problem, or where limited or no fresh water is available for irrigation. Turfgrass developments in these areas are often required to use brackish water from affected wells or other secondary sources. To our knowledge, there are no published studies that have investigated the salt water tolerance among turfgrass species in Malaysia. The proper utilization of highly salt tolerance turfgrass species will give so much benefit to turfgrass area in Malaysia.

The objective of this study was to determine the relative salt tolerance and growth response of warm season turfgrass species grown on sand culture to salinity.

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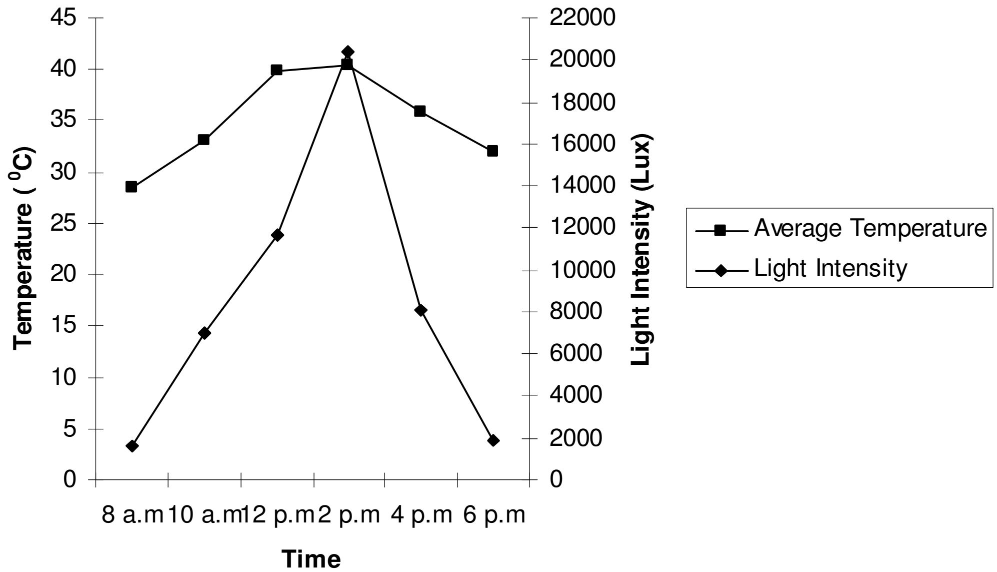

Figure 1. Temperature and light intensity fluctuation in the glass house.

Table 1. Scientific name, common name and subfamily of turfgrass species.

Scientific name	Common name	Subfamily
Axonopus affinis chase	Narrowleaf carpet grass	Panicoideae
Axonopus compressus (Sw) P. Beauv.	Cow grass	Panicoideae
Cynodon dactylon x. *Cynodon transvaalensis*	Bermuda greenless park	Chloridoideae
Cynodon dactylon (L.) Pers.	Common bermuda grass	Chloridoideae
Eremochloa ophiuroides (Munro) Hack.	Centipedegrass	Panicoideae
Paspalum vaginatum Sw.	Seashore paspalum (local)	Panicoideae
Paspalum vaginatum Sw.	Seashore pasplaum	Panicoideae
Zoysia matrella (L.)	Manilagrass	Chloridoideae

MATERIALS AND METHODS

The experiment was conducted in the glasshouse of Faculty of Agriculture at Universiti Putra Malaysia under sand culture system. Eight turfgrass (Table 1) species were planted in plastic pot filled with a mix of 9 washed river sand: 1 peat moss (v/v). The soil was sandy with pH 5.23, EC 0.3 dSm^{-1}, Organic Carbon 0.69%, sand 97.93%, silt 1.89% and clay 0%. The diameter of plastic pots was 14 cm with 15 cm depth. The average day temperature and light intensity of glass-house were 28.5-39.5^{0}C and 1500 - 20400 lux respectively (Figure 1). The temperature was measured by a thermometer and light intensity was measured by heavy duty light meter (Extech ® model 407026). All pots were fertilized with green NPK (15:15:15) @ 0.5 kg / 100 m^2 / month and applied forts nightly. The native soil on the grasses were washed from the sod and then sods were transplanted into the plastic pots and grown for 8 weeks with non-saline irrigation water in order to achieve full establishment. Grasses were clipped by scissors weekly throughout the experiment at the cutting height of 15 mm for course leaf and 5 mm for narrow leaf. The required quantity of sea water was collected from Morib Beach, Selangor, Malaysia. The EC was 48 dSm^{-1}. Four salt water concentrations namely T_1 = 0, T_2 = 24, T_3 = 48 and T_4 = 72 dSm^{-1} were applied in this study. The salinity level was measured by EC meter (HANNA ® model HI 8733). Untreated checks (T_1) were irrigated with distilled water. Seawater was diluted 50% by adding distilled water for treatment T_2. NaCl was added to seawater for T_4 to obtain the salty water level of 72 dSm^{-1}. To avoid salinity shock, salinity levels were gradually increased by daily increments of 8 dSm^{-1} in all treatments until the final salinity levels were achieved. After the targeted salinity levels were achieved, the irrigation water was applied on daily basis for a period of four weeks. The amount of water applied were 200 ml per pot. Data were collected on leaf firing, turf quality, shoot growth and root growth. Leaf firing was estimated as the total percentage of chlorotic leaf area, with 0% corresponding to no leaf firing, and 100% as totally brown leaves. Turf quality was estimated based on a scale of 1 - 9, with 9 as green, dense and uniform turf, and 1 as thin and completely brown turf (Alshammary et al., 2003). At the end of the experiment shoots were harvested and roots were clipped. Both shoots and roots were washed with deioniozed water and dried at 70^{0}C for 72 h to determine root and shoot dry weight. (RCBD) with five replications. The experimental data were analyzed The experimental design was a Randomized Complete Block Design by analysis of variance (SAS Institute, 2004). Treatment means were separated by LSD test. Regression analysis was used to determine the relationship between each variable and the salinity level. Growth measurements (shoot weight and root weight) were expressed as percentages, relative to control and relative growth values are calculated as follows: (Dry weight of salinized treatment value ÷ dry weight of control treatment value) ×100.

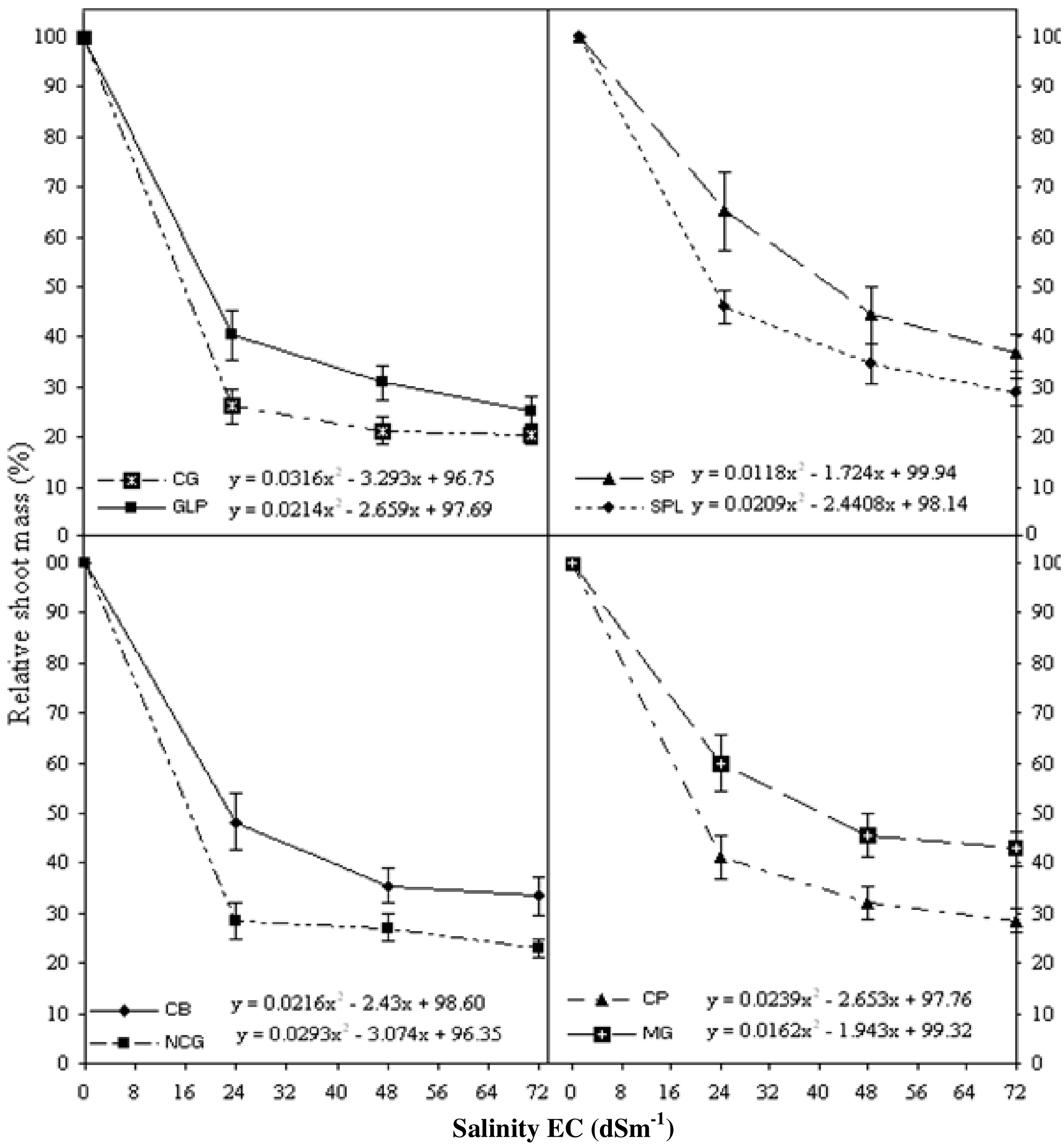

Figure 2. Relative shoot growth of *Axonopus compressus* (CG), *Cynodon dactylon* (GLP), *Paspalum vaginatum* (SP), *Paspalum vaginatum* local (SPL), *Cynodon dactylon* (CB), *Axonopus affinis* (NCG), *Eremochloa ophiuroides* (CP) and *Zoysia matrella* (MG) at different salinity levels. Salinity EC (dSm^{-1}).

RESULTS

Relative shoot growth

Relative shoot growth (as a percent of control) differed significantly among the different turf species (Figure 2). Relative shoot growth decreased with increasing salinity in all species (Figure 2). Regression analysis indicated that *Paspalum vaginatum* (SP), *Zoysia matrella* (MG), *Pasplaum vaginatum* local (SPL), *Cynodon dactylon* (CB), *C. dactylon* (GLP), *Eremochloa ophiuroides* (CP), *Axonopus compressus* (CG) and *A. affinis* (NCG) experienced a 50% shoot growth reduction at 39.8, 36.5, 26.1, 25.9, 21.7, 22.4, 17.0 and 18.3 dSm^{-1} respectively (Figure 2). Relative shoot growth of turf grass *P. vaginatum* (SP) was the highest, followed by *Z. matrella* (MG) while relative shoot growth for *A. compressus* (CG) and *A. affinis* (NCG) reduced drastically were at 24 dSm^{-1} salinity level. However, relative shoot growth of *P. vaginatum* (SP) dramatically decreased at 48 dSm^{-1} salinity which is even lower than that of *P. vaginatum* local (SPL) (Figure 2). Meanwhile relative shoot growth

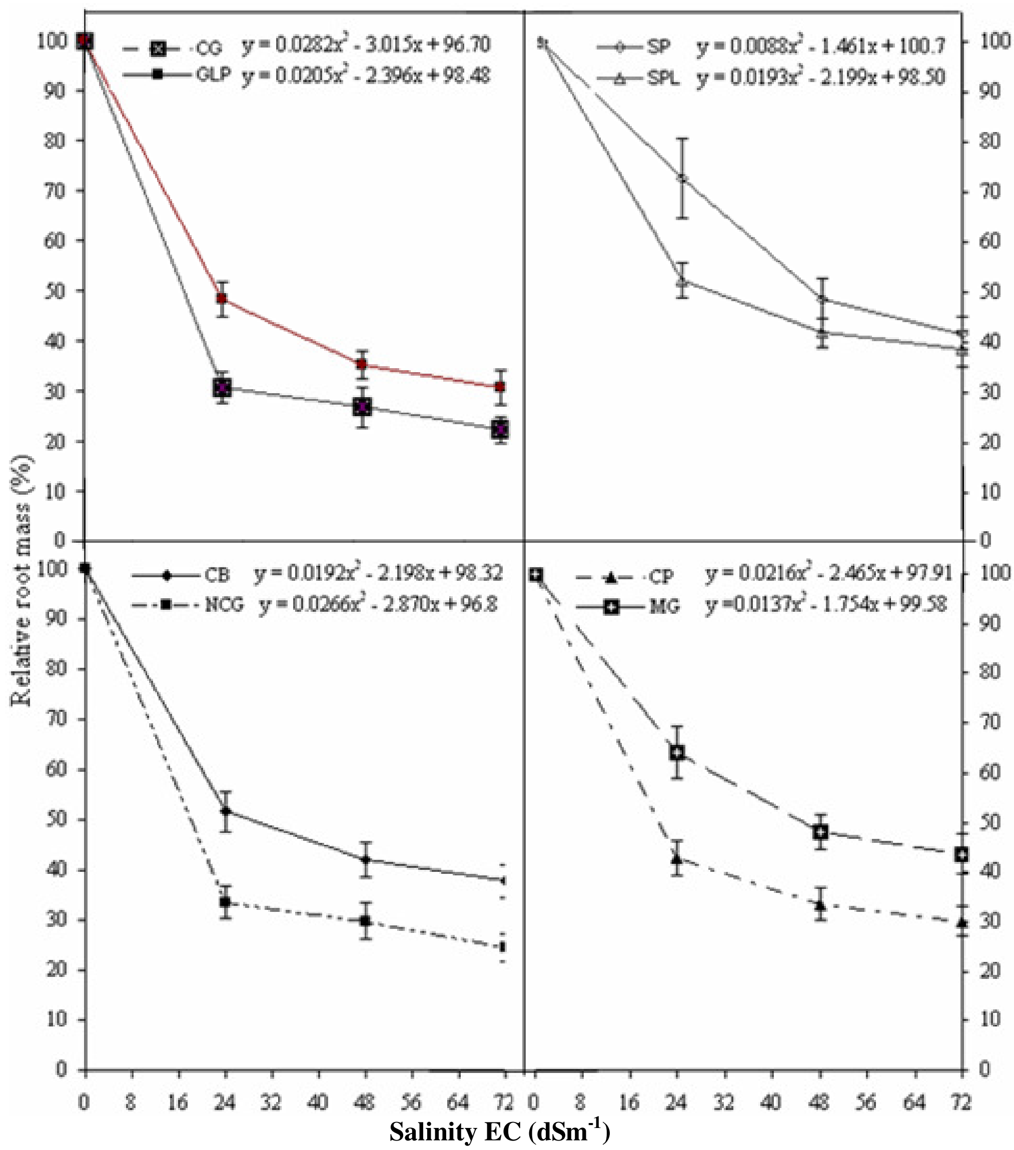

Figure 3. Relative root growth of *Axonopus compressus* (CG), *Cynodon dactylon* (GLP), *Paspalum vaginatum* (SP), *Paspalum vaginatum* local (SPL), *Cynodon dactylon* (CB), *Axonopus affinis* (NCG), *Eremochloa ophiuroides* (CP) and *Zoysia matrella* (MG) at different salinity levels. Salinity EC (dSm^{-1})

was recorded as the highest for *P*. *vaginatum* (SP) at 24 dSm^{-1} followed by *Z. matrella* (MG) while it was recorded the lowest for *A. compressus* (CG) (Figure 2). Relative shoot growth was the lowest for *Z. matrella* (MG) while *P*. *vaginatum* local (SPL) and *E*. *ophiuroides* (CP) were low statistically identical in their growth at 48 dSm^{-1}. Relative shoot growth was signifi-cantly reduced in *A*. *compressus* (CG) and *A. affinis* (NCG). Similar trend was observed at the highest salinity level of 72 dSm^{-1}.

Relative root growth

Root growth of all species decreased as salinity levels increased. Statistical analysis showed that the linear polynomial contrast was significant (Figure 3). Regres-sion analysis predicted that 50% root growth reduction would occur in *P. vaginatum* (SP), *Z. matrella* (MG), *P. vaginatum* local (SPL), *C. dactylon* (CB) *C. dactylon* (GLP), *E. ophiuroides* (CP), *A. compressus* (CG) and *A. affinis* (NCG) at 49.4, 42.1, 29.9, 29.7, 26.0 24.8, 18.8 and 20.0dSm^{-1} respectively (Figure 3). Root growth declined under salinity, although *P. vaginatum* (SP) and *Z. matrella* (MG) had greater relative root growth over all salinity levels than other grasses. Likewise shoot growth, root growth were less affected by *P. vaginatum* (SP) and *Z. matrella* (MG) at 24 dSm^{-1}, while root growth drastically

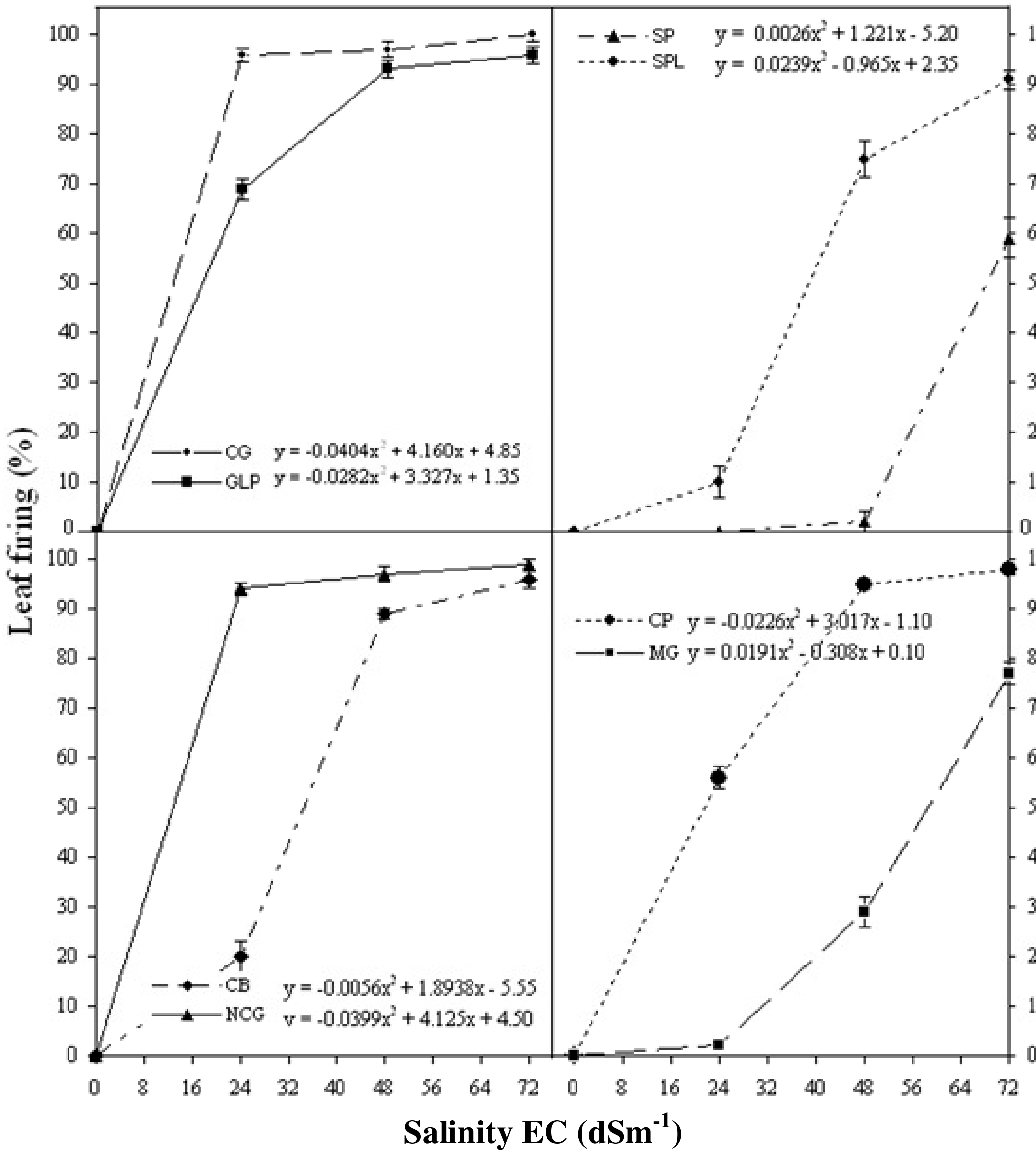

Figure 4. Leaf firing of *Axonopus compressus* (CG), *Cynodon dactylon* (GLP), *Paspalum vaginatum* (SP), *Paspalum vaginatum* local (SPL), *Cynodon dactylon* (CB), *Axonopus affinis* (NCG), *Eremochloa ophiuroides* (CP) and *Zoysia matrella* (MG) at different salinity levels. Salinity EC (dSm^{-1})

reduced in *A. compressus* (CG) and *A. affinis* (NCG). At this salinity level, relative root growth of *P. vaginatum* (SP) was the highest (72.8%) followed by *Z. matrella* (MG) (64.1%) while significantly reduced root growth were observed in *A. affinis* (NCG) (33.6%) and *A. compressus* (CG) (30.7%). At 48 dSm^{-1}, relative root growth was also found to be the highest in *P. vaginatum* (SP) (48.8%) followed by *Z. matrella* (MG) (48.1%) while relative root growth for *A. affinis* (NCG) (29.8%) and *A. compressus* (CG) (26.7%) were badly affected at this salinity level. At 72 dSm^{-1}, relative root growth was 43.7% in *Z. matrella* (MG) followed *P. vaginatum* (SP) (41.9%) while relative root growth of *A. compressus* (CG) and *A. affinis* (NCG) were 22.8%, 24.6% respectively (Figure 3).

Leaf firing

Regardless of turf grass species, leaf firing increased with increasing salinity, reaching 94-100% at the extreme salinity treatment of 72 dSm^{-1} (Figure 4). How-ever, there were less salinity injury noticeable in *P. vaginatum* (SP) and *Z. matrella* (MG) at all salinity levels (Figure 4) compared to other grasses. Leaf of *P. vaginatum* (SP) was unaffected at 24 dSm^{-1} while at 94-100% leaf firing was noticeable in *A. affinis* (NCG) and *A. compressus* (CG) (Figure 4). However, leaf firing was moderately similar (55%) in *E. ophiuroides* (CP) and *C. dcatylon* (GLP) at 24 dS m^{-1} (Figure 4). At 48dSm^{-1}, leaf firing was high in *A. affinis* (NCG) (97%) *E. ophiuroides* (96%) while in *C.*

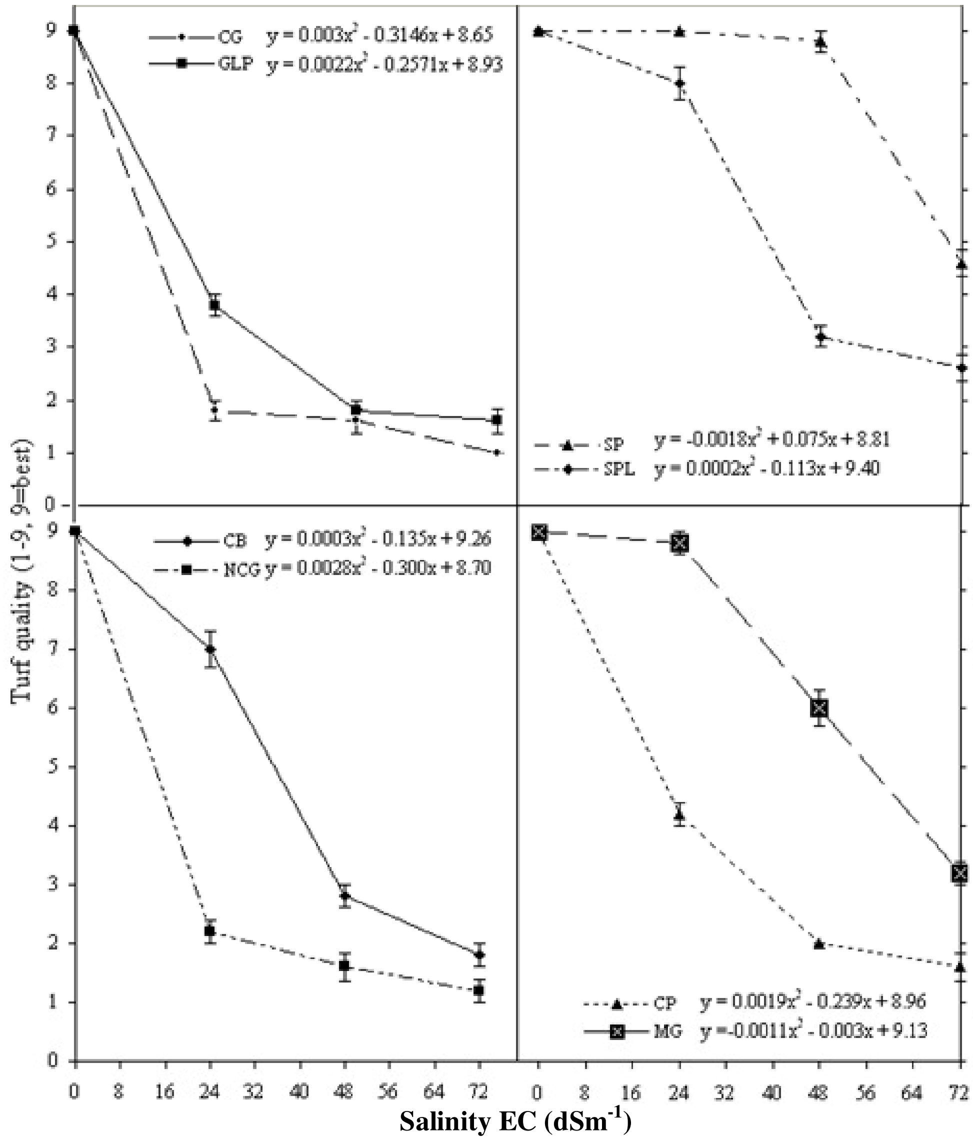

Figure 5. Turf quality of *Axonopus compressus* (CG), *Cynodon dactylon* (GLP), *Paspalum vaginatum* (SP), *Paspalum vaginatum* local (SPL), *Cynodon dactylon* (CB), *Axonopus affinis* (NCG), *Eremochloa ophiuroides* (CP) and *Zoysia matrella* (MG) at different salinity levels. Salinity EC (dSm^{-1})

dactylon (GLP) 69 to 92% (Figure 4). The least leaf firing (59%) was observed in *P. vaginatum* (SP). The same trend was observed at 72 dSm^{-1}, where 90-95% leaf firing was observed in *C. dcatylon* (CB), *P. vaginatum* local (SPL), *C. dactylon* (GLP), *E. ophiuroides* (CP) *A. affinis* (NCG) and *A. compressus* (CG). *P. vaginatum* (SP) and *Z. matrella* (MG) were moderately affected with 59 and 81% respectively.

Turf quality

Turf quality under salt stress as indicated by visual ratings is presented in Figure 5. Turf quality decreased with increasing salinity level. Turf quality decreased severely in *A. affinis* (NCG) and *A. compressus* (CG) while *P. vaginatum* (SP) and *Z. matrella* (MG) exhibited the best turf quality among the entries at all salinity levels (Figure 5). Other four species including *P. vaginatum* local (SPL), *C. dactylon* (GLP), *E. ophiuroides* (CP) *C. dactylon* (CB) were intermediate in their quality ranking. At 24 dSm^{-1} turf quality was unaffected in *P. vaginatum* (SP) (9) but was slightly decreased in *Z. matrella* (8) (Figure 5). However, turf quality was drastically reduced in *A. affinis* (NCG) (2) and *A. compressus* (CG) (2) but was moderate (4 - 8) in *P. vaginatum* local (SPL), *C. dcatylon* (CB), *C. dcatylon* (GLP) and *E. ophiuroides* (CP). At 48 dSm^{-1}, only *P. vaginatum* (SP) kept their quality high (8.8) while it was decreased in *Z. matrella* (MG) (6.0). Turf quality was badly affected in *E. ophiuroides* (CP) (2.0), *A. affinis* (NCG) (1.6), *A. compressus* (CG) (1.6), *C. dcatylon* (CB) (2.8) and *C. dcatylon* (GLP) (1.8) at the same salinity levels. At 72 dSm^{-1}, turf quality was decreased significantly in all turfgrass tested in this experiment.

DISCUSSION

Growth parameters, such as shoot growth (Francois, 1988; Marcum and Murdoch, 1990), root mass (Marcum and Kopec, 1997) and turf quality (Dean et al., 1996; Marcum and Kopec, 1997; Marcum, 1999) have been reported to be excellent criteria to determine salinity tolerance among turfgrasses. Assesment of salinity tolerance using percent leaf firing has been reported in previous studies (Marcum, 1999; Lee et al., 2004b). Leaf firing can be included in salinity assessment as one criterion because leaf firing is easily measured. Relative shoot growth (as a percent of control) decreased with increasing salinity in all species. A tolerance criteria commonly used in salinity studies is the salinity level that result in 50% shoots dry weight reduction relative to the control (Lee et al., 2004a; Mass, 1986). In terms of interactions among soil, plant and surrounding environmental factors during field evaluation, relative yield response is beneficial where comparing salinity tolerance across crop species and environments.

In our studies, based on data on growth parameters (relative shoot growth, 50% shoot growth reduction, leaf firing and turf quality) the salinity tolerance ranking of selected grasses from the most tolerant to less tolerant was *P. vaginatum* (SP), *Z. matrella* (MG), *P. vaginatum* local (SPL), *C. dcatylon* (CB), *C. dcatylon* (GLP), *E. ophiuroides* (CP), *A. affinis* (NCG) and *A. compressus* (CG). Shoot growth rates of *P. vaginatum* and *Z. matrella* were higher than other grasses at all salinity levels. Marcum and Murdoch (1994) reported that relative shoot growth (as a percent of control) was reduced by 50% at the salinity level of 36.4 dSm^{-1} NaCl in *P. vaginatum* and 35.9 dSm^{-1} in *Z. matrella*. Lee et al., (2005) also reported that seashore paspalum were able to maintain 50% of shoot dry weight relative to the control up to 37 dSm^{-1}. Shoot growth and turf quality of turfgrass were reduced as the salinity level of irrigation water increased (Peacock and Dudeck, 1985; Dean et al., 1996).

Based on this result *P. vaginatum* (SP) and *Z. matrella* (MG) were the two most salt tolerant turdgrass species. *P. vaginatum* (SP) is one of the most salt tolerant turfgrass cultivars; even seawater with 54 dSm^{-1} can be used for irrigation (Duncan and Carrow, 2000). Bermudagrass is listed as salt tolerant by Carrow and Duncan (1998). In our study *P. vaginatum* local (SPL) and *C. dcatylon* (CB) were more salt tolerant than *A. compressus* (CG), *A. affinis* (NCG), *C. dcatylon* (GLP) and *E. ophiuroides* (CP). Dudeck et al. (1983) reported that common bermuda is less salt tolerant than Tifgreen and Tifdwarf.

Growth limitation at high salinity may be due to depletion of energy that is needed for growth and the loss of turgor (Marcum, 2006). Root growth stimulation under saline condition has been observed in bermuda grass (Dudeck et al., 1983) and seashore paspalum (Dudeck and Peacock, 1993).

Conclusion

The relative salinity tolerance of turfgrass root growth, shoot growth and leaf firing were closely associated with salinity tolerance of the grasses. The different species of grasses were grouped for salinity tolerance on the basis of 50% shoot and root growth of reduction, leaf firing and turf quality with increasing salinity. The first groups was the most tolerant species including *P. vaginatum* (SP) and *Z. matrella* (MG) which were able to tolerant high levels of salinity between 36.5 to 49.4 dSm^{-1}. In the second group were the moderate tolerant species including *P. vaginatum* local (SPL) and *C. dactylon* (CB) which were able to tolerate salinity level between 25.9 to 29.9 dSm^{-1}, while in the lowest tolerant performance group were *C. dactylon* (GLP), *E. ophiuroides* (CP) *A. compressus* (CG) and *A. affinis* (NCG) varieties, which were affected at salinity level of between 17.0 and 26.0 $dS\ m^{-1}$.

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